MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 1, 2014/2015

EEE 3076 – POWER ELECTRONICS

(LE, EE, CE, NE)

18 SEPTEMBER 2014
9.00 AM. – 11.00 AM.
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This Question paper consists of 10 pages including cover page with 4 Questions only.

2. Answer ALL questions. All questions carry equal marks and the distributions of the marks for each question is given.

3. Please print all your answers in the Answer Booklet provided.

Question 1

a) A converter circuit is shown in Figure Q1. It is used to control power level to the load. Select a suitable switch for this application based on datasheets in Appendixes A1-A3. The operating switching frequency of the circuit is 25 kHz. State at least one drawback of the selected switch.

[7 marks]

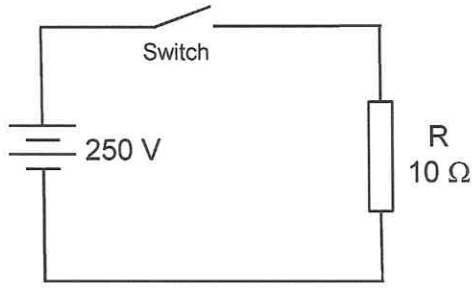


Figure Q1

b) A Power MOSFET (IRFP4137PbF- Appendix A2) is used as a switch for a DC-DC converter connected to an R-L load. The input voltage is 280 V and maximum output current is 18 A. The switch is operated at 20 kHz with 40% duty cycle. Compute the following for the case temperature of 25°C. (hint, $\tau_{ON} = T_{d(on)} + T_r$ and $\tau_{OFF} = T_{d(off)} + T_f$)

(i) Static Loss

[6 marks]

(ii) Dynamic Loss

[9 marks]

(iii) Total Loss

[3 marks]

Continued...

Question 2

Design a full wave rectifier to supply an average DC voltage of 207 V to a Resistive-Inductive load. The maximum average power required by the load is 4 kW. Input AC voltage is 230 V, 50Hz.

a) Sketch the circuit diagram.

[2 marks]

b) Compute the maximum average load current.

[2 marks]

c) Select a suitable switch for the rectifier based on the Table in Appendix B.

[5 marks]

d) Compute the losses in each switch. (Given, $R_{on} = 0.1\ \Omega$.)

[11 marks]

e) Assuming the load inductance is large, sketch the input AC current waveform relative to input AC voltage waveform.

[5 marks]

Continued...

Question 3

(a) A buck-boost converter supplies a 70 W load at a current of 5 A from a 40 V dc source. The switching period is 130 μs and the value of the inductor is 250 μH. Determine the following:

(i) The duty cycle D.

[4 marks]

(ii) The minimum and maximum inductor current (I_{Lmin} , I_{Lmax}).

[4 marks]

(iii) The average input current.

[2 marks]

(iv) The average diode current.

[2 marks]

(b) Design a buck converter to power a load that consumes 18 W. The load requires a voltage with ripple not more than 0.5%. The input voltage V_{in} = 30 V and duty cycle D = 0.4. The switching frequency used to operate the converter is 25 kHz. Assume that the buck converter will be operating in the continuous current mode and all the converter components are ideal.

[13 marks]

Continued...

Question 4

a). Figure Q4(a) shows a single-phase half-bridge inverter which has an input dc voltage of V_p= 230 V and a resistive output load of R_L= 115 Ω.

(i) Draw the output voltage waveform.

[4 Marks]

(ii) Determine the rms value of the fundamental frequency component, the 3rd and 5th order harmonics.

[8 Marks]

(iii) Determine the harmonic factor of the lowest-order harmonic component

[2 Marks]

(iv) Calculate the average output power.

[2 Marks]

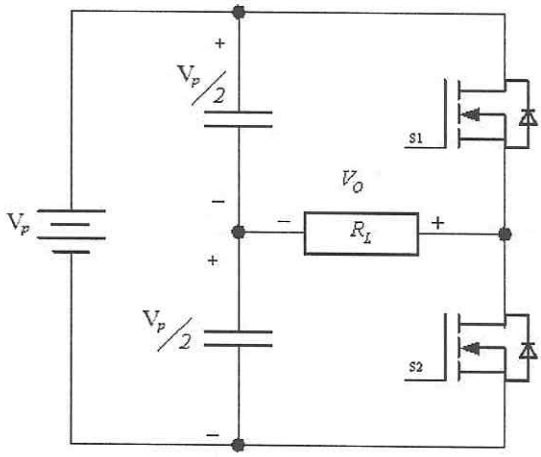


Figure Q4(a)

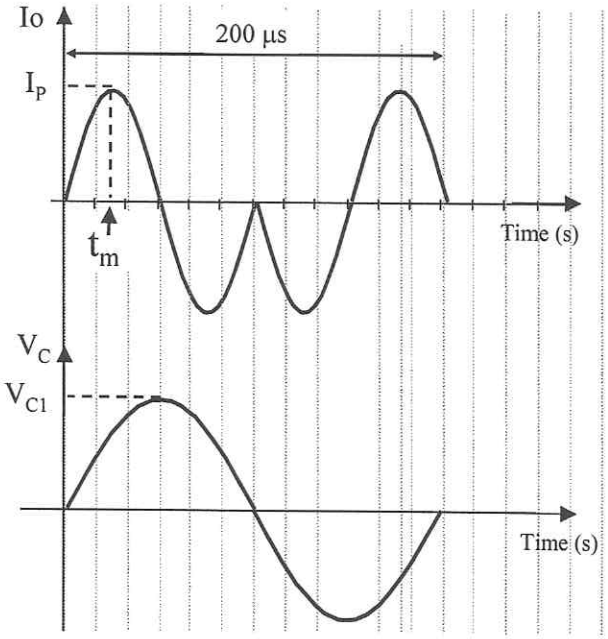


Figure Q4(b)

b). The inverter circuit shown in Figure Q4(a) is modified to create resonant effect to minimize switching losses. For this, the resistive load, R_L is replaced with a resistive-inductive load. Figure Q4(b) shows the output current and capacitor voltage waveforms. Given that $C_1 = C_2 = 2.5$ μF and L = 30 μH, determine the maximum value of resistor, R so that the inverter operates in non-overlapping mode.

[9 marks]

Continued...

Appendix A1

BUF420AW

HIGH VOLTAGE FAST-SWITCHING NPN POWER TRANSISTOR

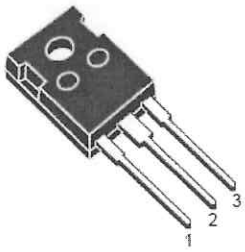
- STMicroelectronics PREFERRED SALESTYPE
- HIGH VOLTAGE CAPABILITY
- VERY HIGH SWITCHING SPEED
- MINIMUM LOT-TO-LOT SPREAD FOR RELIABLE OPERATION
- LOW BASE-DRIVE REQUIREMENTS

APPLICATIONS:
- SWITCH MODE POWER SUPPLIES
- MOTOR CONTROL

DESCRIPTION

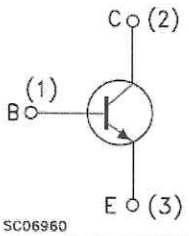
The BUF420AW is manufactured using High Voltage Multi Epitaxial Planar technology for high switching speeds and high voltage capacity. It uses a Cellular Emitter structure with planar edge termination to enhance switching speeds while maintaining a wide RBSOA.

The BUF series is designed for use in high-frequency power supplies and motor control applications.



TO-247

INTERNAL SCHEMATIC DIAGRAM



ABSOLUTE MAXIMUM RATINGS

Symbol	Parameter	Value	Unit
V_{CEV}	Collector-Emitter Voltage (V_{BE} = -1.5V)	1000	V
V_{CEO}	Collector-Emitter Voltage (I_B = 0)	450	V
V_{EBO}	Emitter-Base Voltage (I_C = 0)	7	V
I_C	Collector Current	30	A
I_{CM}	Collector Peak Current (t_p < 5 ms)	60	A
I_B	Base Current	6	A
I_{BM}	Base Peak Current (t_p < 5 ms)	9	A
P_{tot}	Total Dissipation at T_c = 25 °C	200	W
T_{stg}	Storage Temperature	-65 to 150	°C
T_j	Max. Operating Junction Temperature	150	°C

Continued...

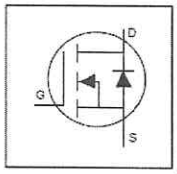
Appendix A2-1

International
IOR Rectifier

IRFP4137PbF

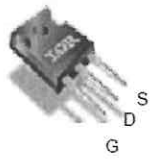
HEXFET® Power MOSFET

Application
- High Efficiency Synchronous Rectification in SMPS
- Uninterruptible Power Supply
- High Speed Power Switching
- Hard Switched and High Frequency Circuits



V_{DSS}	300V
$R_{DS(on)}$ typ.	56mΩ
max	69mΩ
I_D	38A

Benefits
- Improved Gate, Avalanche and Dynamic dV/dt Ruggedness
- Fully Characterized Capacitance and Avalanche SOA
- Enhanced body diode dV/dt and dI/dt Capability
- Lead-Free, RoHS Compliant



TO-247AC

G	D	S
Gate	Drain	Source

Base part number	Package Type	Standard Pack		Orderable Part Number
		Form	Quantity	
IRFP4137PbF	TO-247AC	Tube	25	IRFP4137PbF

	Parameter	Max.	Units
I_D @ T_C = 25°C	Continuous Drain Current, V_{GS} @ 10V	38	A
I_D @ T_C = 100°C	Continuous Drain Current, V_{GS} @ 10V	27	
I_{DM}	Pulsed Drain Current ①	152	
P_D @T_C = 25°C	Maximum Power Dissipation	341	W
	Linear Derating Factor	2.3	W/°C
V_{GS}	Gate-to-Source Voltage	± 20	V
dv/dt	Peak Diode Recovery dv/dt③	8.9	V/ns
T_J T_{STG}	Operating Junction and Storage Temperature Range	-55 to + 175	°C
	Soldering Temperature, for 10 seconds (1.6mm from case)	300	
	Mounting Torque, 6-32 or M3 Screw	10 lbf·in (1.1 N·m)	

Avalanche Characteristics

$E_{AS\ (Thermally\ limited)}$	Single Pulse Avalanche Energy ②	541	mJ

Thermal Resistance

	Parameter	Typ.	Max.	Units
$R_{\theta JC}$	Junction-to-Case ⑧	—	0.44	°C/W
$R_{\theta CS}$	Case-to-Sink, Flat Greased Surface	0.24	—	
$R_{\theta JA}$	Junction-to-Ambient ⑦⑧	—	40	

Continued…

Appendix A2-2

IOR IRFP4137PbF

Static @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions
$V_{(BR)DSS}$	Drain-to-Source Breakdown Voltage	300	—	—	V	V_{GS} = 0V, I_D = 250µA
$\Delta V_{(BR)DSS}/\Delta T_J$	Breakdown Voltage Temp. Coefficient	—	0.24	—	V/°C	Reference to 25°C, I_D = 3.5mA
$R_{DS(on)}$	Static Drain-to-Source On-Resistance	—	56	69	mΩ	V_{GS} = 10V, I_D = 24A ④
$V_{GS(th)}$	Gate Threshold Voltage	3.0	—	5.0	V	V_{DS} = V_{GS}, I_D = 250µA
I_{DSS}	Drain-to-Source Leakage Current	—	—	20	µA	V_{DS} =300 V, V_{GS} = 0V
		—	—	250		V_{DS} =300V,V_{GS} = 0V,T_J =125°C
I_{GSS}	Gate-to-Source Forward Leakage	—	—	100	nA	V_{GS} = 20V
	Gate-to-Source Reverse Leakage	—	—	-100		V_{GS} = -20V
R_G	Gate Resistance	—	1.3	—	Ω	

Dynamic Electrical Characteristics @ T_J = 25°C (unless otherwise specified)

gfs	Forward Transconductance	45	—	—	S	V_{DS} = 50V, I_D =24A
Q_g	Total Gate Charge	—	83	125	nC	I_D = 24A
Q_{gs}	Gate-to-Source Charge	—	28	42		V_{DS} = 150V
Q_{gd}	Gate-to-Drain Charge	—	26	39		V_{GS} = 10V
$t_{d(on)}$	Turn-On Delay Time	—	18	—	ns	V_{DD} = 195V
t_r	Rise Time	—	23	—		I_D = 24A
$t_{d(off)}$	Turn-Off Delay Time	—	34	—		R_G= 2.2Ω
t_f	Fall Time	—	20	—		V_{GS} = 10V
C_{iss}	Input Capacitance	—	5168	—	pF	V_{GS} = 0V
C_{oss}	Output Capacitance	—	300	—		V_{DS} = 50V
C_{rss}	Reverse Transfer Capacitance	—	77	—		f = 1.0MHz
$C_{oss\ eff.(ER)}$	Effective Output Capacitance (Energy Related)	—	196	—		V_{GS} = 0V, VDS = 0V to 240V⑥ See Fig.11
$C_{oss\ eff.(TR)}$	Output Capacitance (Time Related)	—	265	—		V_{GS} = 0V, VDS = 0V to 240V⑤

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Appendix A3

PD - 97426

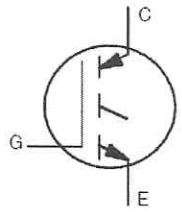
International
IOR Rectifier

INSULATED GATE BIPOLAR TRANSISTOR

IRGP4069PbF
IRGP4069-EPbF

Features

- Low $V_{CE\ (ON)}$ Trench IGBT Technology
- Low Switching Losses
- Maximum Junction Temperature 175 °C
- 5 µS short circuit SOA
- Square RBSOA
- 100% of The Parts Tested for I_{LM}
- Positive $V_{CE\ (ON)}$ Temperature Coefficient
- Tight Parameter Distribution
- Lead Free Package



n-channel

V_{CES} = 600V

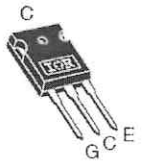
$I_{C(Nominal)}$ = 35A

$t_{SC} \geq 5\mu s$, $T_{J(max)}$ = 175°C

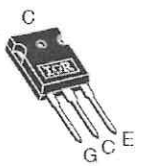
$V_{CE(on)}$ typ. = 1.6V

Benefits

- High Efficiency in a Wide Range of Applications
- Suitable for a Wide Range of Switching Frequencies due to Low $V_{CE\ (ON)}$ and Low Switching Losses
- Rugged Transient Performance for Increased Reliability
- Excellent Current Sharing in Parallel Operation



TO-247AC
IRGP4069PbF



TO-247AD
IRGP4069-EPbF

G	C	E
Gate	Collector	Emitter

Absolute Maximum Ratings

	Parameter	Max.	Units
V_{CES}	Collector-to-Emitter Voltage	600	V
I_C @ T_C = 25°C	Continuous Collector Current	76	A
I_C @ T_C = 100°C	Continuous Collector Current	50	
$I_{NOMINAL}$	Nominal Current	35	
I_{CM}	Pulse Collector Current, V_{GE} = 15V	105	
I_{LM}	Clamped Inductive Load Current, V_{GE} = 20V ①	140	
V_{GE}	Continuous Gate-to-Emitter Voltage	±20	V
	Transient Gate-to-Emitter Voltage	±30	
P_D @ T_C = 25°C	Maximum Power Dissipation	268	W
P_D @ T_C = 100°C	Maximum Power Dissipation	134	
T_J	Operating Junction and	-55 to +175	°C
T_{STG}	Storage Temperature Range		
	Soldering Temperature, for 10 sec.	300 (0.063 in. (1.6mm) from case)	
	Mounting Torque, 6-32 or M3 Screw	10 lbf·in (1.1 N·m)	

Thermal Resistance

	Parameter	Min.	Typ.	Max.	Units
$R_{\theta JC}$	Thermal Resistance Junction-to-Case ④	—	—	0.56	°C/W
$R_{\theta CS}$	Thermal Resistance, Case-to-Sink (flat, greased surface)	—	0.24	—	
$R_{\theta JA}$	Thermal Resistance, Junction-to-Ambient (typical socket mount)	—	—	40	

Continued...

Appendix B

Part Number	Package	Repetitive Peak Reverse Voltage(VRRM) max (V)	Average Rectified Current(Io) max (A)	Forward Voltage(Vf) max (V)	Reverse Current(IR) max (mA)	Reverse Recovery Time(trr) max (ns)	Junction Temperature(Tj) max (°C)
STTH1003S-Y	DPAK	300	10	1.3	0.1	35	175
STTH102-Y	SMA	200	1	0.97	0.001	20	175
STTH1R04-Y	SMA; SMB	400	1	0.9	0.05	20	175
STTH2R02-Y	SMB	200	2	1	0.003	20	175
STTH30R04-Y	DO-247; TO-220AC	400	30	1	0.03	45	175
STTH4R02-Y	SMB; SMC	200	4	1.05	0.003	20	175
STTH802-Y	DPAK	200	8	1.05	0.006	30	175

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